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4

MANAGEMENT APPROACH RECOMMENDATIONS

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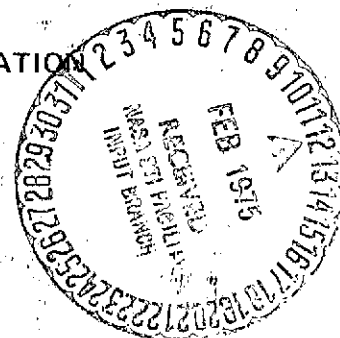
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EARTH OBSERVATORY SATELLITE SYSTEM DEFINITION STUDY (EOS)

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER

IN RESPONSE TO
CONTRACT NAS5-20519



TRW
SYSTEMS GROUP

ONE SPACE PARK • REDONDO BEACH, CALIFORNIA 90278

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GLOSSARY

CCN	Contract change notice
CDR	Critical design review
CM	Configuration management
ECP	Engineering change proposals
FMEA	Failure modes and effects analysis
FMECA	Failure modes, effects, and criticality analyses
ICD	Interface control drawing
MPS	Master program schedule
PM&P	Parts, materials, and processes
ROM	Rough order of magnitude
WBS	Work breakdown structure

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1. INTRODUCTION

The EOS program opens a new era in unmanned spacecraft, both in technology and management concepts. Accompanying this new era of spacecraft technology are fiscal constraints which require innovative approaches to achieve minimum costs -- costs that are predictable with a high confidence.

The primary emphasis during the first decade and a half of space flight has been on performance. New technologies to be explored, new hardware to be developed, new techniques to accomplish, new tasks all required large staffs of scientists and engineers together with new facilities and equipment. Obviously cost goals were far down on the list of priorities. Contracts for many programs were in fact structured so that there were built-in incentives for both the contractor and contracting agency keeping costs up.

Today "space" is a maturing industry and the emphasis must shift to make cost the primary priority. Precedents exist in other industries, where competitive cost pressures have forced such reemphasis -- for example, nuclear power. In a coming era of a substantially static space budget, only by lowering space costs can we increase the total number of space flights. These points are well discussed by A. O. Tischler who said:¹

"The first decade of space was characterized by unprecedented missions, each pushing technological frontiers on many boundaries. The pioneering thrust made performance and mission success the governing objectives, with cost a dependent variable.

Now space programs have achieved a maturity that permits confidence in the ability to do difficult missions. Many of the necessary technologies have progressed well up the learning curve, and additional performance gains are often unnecessary. At such a point, cost should become a parameter in design. The "best" design, always a compromise, must now mean "best value." The new problem is to enhance the productivity of the space program in practical uses for direct benefit of the public."

¹ "Lower Space Costs Mean More Space Flight," A. O. Tischler, June 1974, Astronautics and Aeronautics

The spacecraft industry has matured to the point that existing technology can be used to produce off-the-shelf hardware elements that will adequately perform to typical EOS type multimission requirements. The innovative portion of this new program and the method for establishing improved low-cost production and testing techniques are also available.

These techniques hinge on our ability to produce both payload and standard subsystem modules that provide performance versatility to span wide ranges of mission and interface margins (i. e., launch vehicle, EMC, data bus, power distribution, structure, and thermal) without expensive testing, or loss of confidence. The key is a sound prediction of the requirements and technical capabilities for missions that are 10 to 15 years in the future. Following this approach, a substantial increase can be made in the fraction of program funding directed toward advancing payload technology and/or data usefulness rather than the spacecraft.

The EOS modular approach to provide multimission research/operational spacecraft provides more data-per-dollar than any previous program:

- By integrating each major standard spacecraft subsystem into a self-contained module, we have a flexible spacecraft which accommodates many different payload complements and orbit parameters.
- Modularity makes feasible the in-orbit servicing of the Observatory by Space Shuttle for maintenance or updating. Previous studies have shown Shuttle servicing to be an economical approach to spacecraft system maintenance.

Standardizing modules as far as practicable is accomplished for EOS by isolating the system elements that are independent of payload characteristics, and then grouping these payload-independent elements into subsystem-related functions; the result is a logical module complement usable for many diverse missions with minimum change. Such a module may be specified, procured, tested, and stockpiled for later synthesis of operational observatories.

1.1 COST SAVINGS THROUGH DESIGN APPROACH

(Estimated savings — 25% noncurring, 10% recurring)

- The modularity concept requires a new set of design guidelines if it is to function properly. These guidelines must include the following:
 - Segment each design aspect into its own cubicle and write an independent and complete specification to cover this aspect. Tie each of these segments together with a carefully prepared set of interface specifications. These interface specifications must be clean and concise and allow work to be accomplished at varied locations with excellent fit and performance anticipated at observatory integration.
 - Adequate interface margins, i.e., larger than currently designed for, must be incorporated if the required fit and performance are to be achieved. In addition, these margins must be large enough to accommodate a wide spectrum of future payloads.
 - Develop a system which emphatically discourages any modification to or variation from the interface specifications without thorough knowledge of the impact.
- Higher risk factors (reduced test and verification) can be tolerated in the EOS design than in any previous program, since the Shuttle can be relied on for refurbishment and/or retrieval of the Observatory. Increasing the risk factors allows larger interface margins and this, as previously mentioned, is of tremendous importance to a proper modular fit and performance with limited testing.
- Currently a great deal of spacecraft design incorporates internal redundancy within the black box. This does not allow the NASA project manager any reliability/cost tradeoff flexibility. It is proposed for the standard modules on EOS that redundancy be incorporated, wherever possible, at the black box level. This allows the NASA project manager, when EOS becomes operational, to purchase the redundancy level that best fits his needs.
- During the design phase, cost budgets between the project manager and module managers should be established, agreed upon, and carefully adhered to. In addition, it is recommended that a special award system be instituted to encourage spending less dollars than the budget. Although cost budgets are difficult to arrive at, the maturity of spacecraft technology today and judicious appraisal of previous programs permit accurate goals to be established.

1.2 COST SAVINGS IN MANUFACTURE AND TEST (Estimated savings - 10% recurring)

- Two different approaches to reduced-cost EOS manufacturing are possible:
 - Dollar savings can be realized by allowing the manufacturing at a low overhead facility while the design and development (through drawings and specifications) are performed at one of the high technology (higher overhead) companies. A certain amount of relaxation, in terms of paperwork and controls and use of existing procedures, should also be a part of this particular low-cost package.
 - Establish a facility as part of a high technology company where approximately 90 percent of the total EOS Observatory (excepting payloads) could be designed, developed, fabricated, integrated, and tested. This reduces immensely the problems and cost of communications between companies and allows for better development of team morale and closer coordination with the customer.
- Perform extensive qualification testing to validate the modular design parameters and limit acceptance testing at spacecraft and observatory level. This significantly reduces costs compared to the conventional approach.
- Employ a single contractor to perform the integration and test functions for both modules and observatory. One test laboratory and the same personnel are used to preclude redundant testing between the module and observatory levels, only one set of EGSE and MGSE are required, start-up and familiarization costs are greatly reduced and the use of similar plans and procedures for the module and observatory further reduces costs.
- Establish a central parts procurement program to procure high-usage parts in large lots. This ensures a supply of high-reliability parts at considerably less cost and eliminates schedule problems caused by parts availability.
- Maintain a strong parts standardization program. This reduces costs while providing parts that have been thoroughly tested and are available for large lot buys.
- To cut quality assurance costs, utilize the contractor's existing Quality Manual in lieu of preparing a new plan for EOS, reduce inspection documentation, allow the contractor to control disposition of inconsequential discrepancies, and use standard contractor functional audits in place of special project audits.

- Reduce reliability engineering costs by limiting failure modes and effects analysis primarily to areas concerning interfaces between boxes, reducing the formality of failure reporting and analysis, limiting reliability assessment analysis, and providing only summary data as formal documentation.

1.3 COST SAVINGS THROUGH ORGANIZATION AND MANAGEMENT (Estimated savings — 10% nonrecurring, 5% recurring)

- Definitive requirements, well-understood specifications, agreement on design approach, and well understood costs at the outset — these are the major factors in achieving a low-cost program. This is where program costs have typically gone "out-of-sight" because performance specifications prove to be pushing the state of the art unbeknown to either the government or the contractor. To preclude this on the EOS program, we recommend that the first phase of the program be devoted to an in-depth reexamination of the Phase B effort by a relatively small team of senior engineers. This team should work from 3 to 6 months to determine with high confidence all basic technical performance requirements before the detailed design and hardware phase commences.
- A dedicated project type organization with all the design personnel collocated in one facility is the most cost-effective approach for a spacecraft design that is within the state of the art. Collocating a strong NASA management team in the project office facilitates communications and allows timely decisions.
- The most cost-effective project control system uses the contractor's existing system. Coupled with an earned value capability (for progress measurement) and a design-to-cost system (for recurring cost measurement), the contractors internal system can provide the basic data needed by internal EOS project management to control cost and schedule performance and to report progress to NASA.
- Manpower costs will be reduced by limiting formal design reviews to the module level (and higher), and holding only informal reviews at the black box level. At formal reviews customer participation is at its peak and the contractor responds with an and excessive expenditure of manpower/costs. Requiring only informal working reviews at the black box level minimizes this type of response.
- For formal configuration control with the customer, limit control documents to the statement of work, system specification, and interface control specifications. Release black box specifications after the critical design review and allow control by the subsystem manager.
- Document preparation costs can be reduced by deleting the formal submission requirement for many documents and using informal information available at the contractors. A preliminary EOS documents list is provided in Section 2.

1.4 COST SAVINGS THROUGH METHOD OF CONTRACTING

(Estimated savings — 15% nonrecurring, 5% recurring)

- NASA continues as the contracting agency for the payload throughout the program. This approach provides the greatest confidence and the lowest cost, since NASA already has an experienced team developing EOS instruments and G and A is eliminated. (Technical assistance can be provided by the contractor, as required.)
- A combination CPIF/CPAF contract is used for the systems integrator. CPIF incentives are used on cost and measureable parameters, while CPAF incentives are used on non-quantifiable parameters, such as management performance and payload interface management.
- The "Contract Changes" clause is eliminated and every departure from the original negotiated agreement is done by bilateral action (supplemental agreement). This eliminates questionable changes and decreases the cost of contract change administration.
- The contract provides zero fee for all contractor-initiated changes and doubles the fee rate for all NASA-directed changes. This discourages change activity on the part of both parties.
- All program cost savings originated by the contractor are shared on a predetermined percentage basis to motivate the contractor to cut costs.
- A formal contractor program is implemented for cost awareness and personnel motivation.

Further details on the management techniques summarized above are included in Sections 2 through 5 of this report.

2. MANAGEMENT APPROACH

2.1 INTRODUCTION

During the EOS System Definition Study, we performed management analyses and tradeoffs to determine the most cost-effective simplified management approach for the EOS Phase C/D. Three basic objectives had to be met by the selected management approach.

- 1) It must be scheduled and organized to produce the most cost effective approach
- 2) It must give an accurate measurement of progress
- 3) It must provide a system for measuring and controlling the recurring production costs of the spacecraft modules.

To meet these goals we recommend:

- A startup phase of 3 to 6 months by a small team of senior engineers who will continue to reexamine multimission flexibility and provide clean interface margins
- A dedicated project type organization, with senior NASA personnel collocated in the project office to increase communications and allow timely decisions
- Utilizing a program control system with an earned value capability (for progress measurement) and a design-to-cost system (for recurring cost measurement) coupled with a streamlined project planning approach; a low-cost performance measurement system (PMS) can be implemented that serves the contractor's internal EOS project management and also provides a basis for developing data to be submitted to NASA
- Formal design reviews be limited to system and subsystem level, and informal reviews used at the black box level
- A simplified manual schedule control system be used
- For formal configuration control, limit the control documents to the statement of work, system specification, and interface control specifications. Release black box specifications after critical design review and allow control by the subsystem manager.
- Limit required documentation and distribution of documents.

The following paragraphs describe these recommendations and summarize the rationale for their use in reducing EOS costs.

2.2 CONTRACT STARTUP PHASE

In the Phase B study reports and in the proposal for Phase C/D, the contractor identifies specific design concepts. These design concepts have been prepared without the benefit of in-depth discussions with NASA because of government restrictions during the competitive procurement. After a contractor is selected these concepts are usually modified to incorporate specific customer suggestions, since this is the first time a complete exchange of ideas is permitted. These modifications cause problems if the program starts in the normal mode with strong schedule and performance pressures. In addition, in the early design phase of the program new design requirements are usually discovered -- again causing a program perturbation. These changes have significant cost implications, especially if they are implemented while the program is proceeding at full speed.

To avoid these problems, TRW recommends that the first phase of the EOS program be devoted to an in-depth reexamination of the Phase B effort by a relatively small team of senior engineers. The work should proceed to a level that permits all basic technical performance requirements to be determined with high confidence before the detailed design and hardware phase commences. Sufficient time must be allowed to work the design in an optimum environment (without the high pressure of schedule and normal program cost expenditures). This effort, lasting 3 to 6 months, should remove any unknowns in the program and allow the program to proceed with a much lower cost risk.

2.3 PROGRAM ORGANIZATION

We examined the various types of organizations used for managing spacecraft programs in the past and concluded that a dedicated project type organization with all the design personnel collocated in one facility is the most cost effective approach for a spacecraft design that is within the state of the art. The EOS design criteria fits this requirement. This

type of organization is especially suitable for a program that is low-cost oriented, since it allows close fiscal controls. We also recommend that NASA consider collocating a strong management team at the contractor's facility to increase efficiencies in communication between the two organizations. Significant cost reduction would be possible if the collocated NASA team is given sufficient decision-making authority; important decisions can be made in a timely manner, and the documentation preparation and general paper flow would be reduced. A suggested project organization is shown in Figure 2-1.

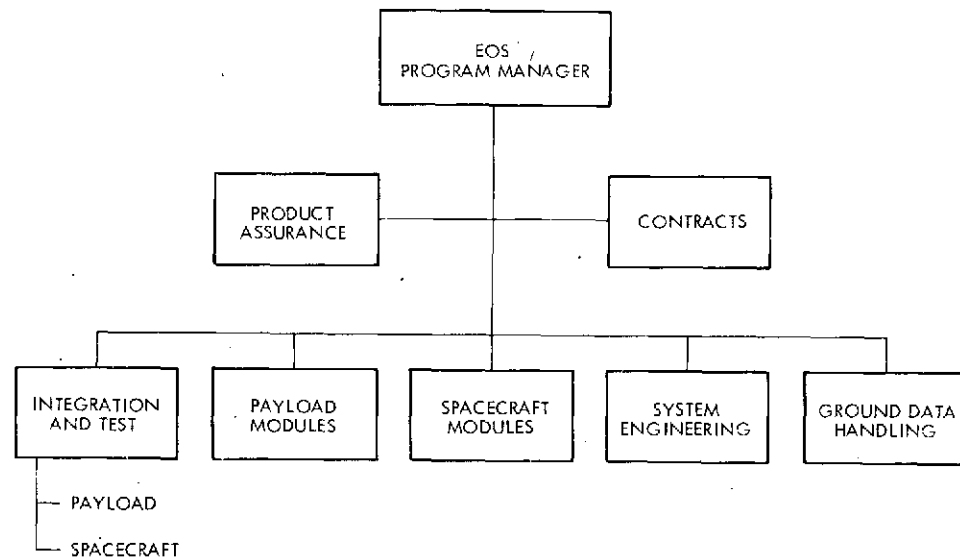


Figure 2-1. EOS Project Organization

This project organization is responsible for overall project technical, cost, and schedule performance, and specifically responsible for:

- Realizing the goals of a low-cost development
- Project systems engineering, and integration and technical project management through all phases of the project
- Official communications and liaison with NASA and other project elements
- Establishment and control of overall project budgets, schedules, and in keeping with the strong cost objectives of the program to produce the most efficient organization possible
- Management of the activities of all personnel assigned directly to the project.

As the program proceeds through the phases of design, development, manufacturing, test, and integration, the project organization is modified to phase out completed operations and strengthen other operations. The final major phase of the program, integration and test, would have the reduced project office shown in Figure 2-2.

2.4 PROJECT MANAGEMENT CONTROL SYSTEM

The results of our management tradeoff studies clearly indicate that the salient elements of the contractor's existing project management systems should be utilized to establish the most cost-effective method for management control for the EOS Phase C/D Project. In addition to the

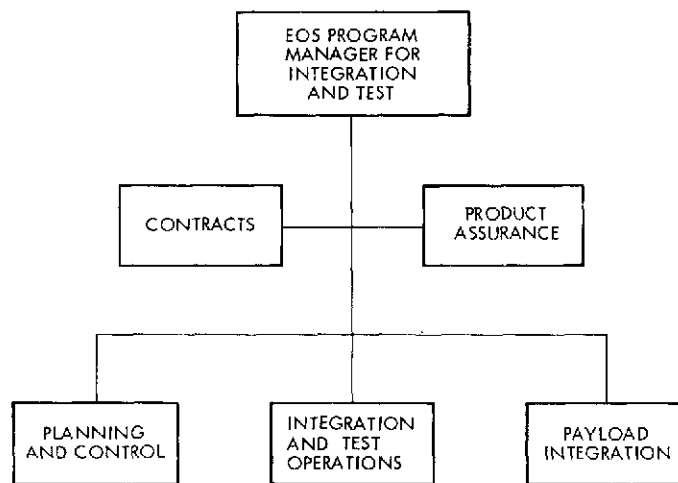


Figure 2-2. Project Organization for Final Phase

basic tools used for management control (design reviews for technical performance, schedule control for program status, and cost reporting for financial status), an earned value system is recommended which relates cost, schedule, and technical progress to give an accurate picture of overall program status. These management techniques are described below.

2.4.1 Design Review

The primary purpose of a design review is to ascertain if the design approach agrees with the specification and cost goals. To ensure these goals are met in EOS, we recommend:

- Limit formal design reviews to the system and subsystem level and hold only informal reviews at the black box level. At formal reviews customer participation is at its peak and the contractor responds with an excessive expenditure of manpower/costs. By requiring only informal working reviews at the black box level, frequent customer interchange occurs without the need for a massive immediate response by the design group. Customer's recommendations are then evaluated and incorporated in the normal everyday work.

- Specialists from manufacturing, test, and costing will form the core of the design review team. The reviews will stress the cost of development and production.

2.4.2 Schedule Control

EOS schedule control would be keyed to scheduled milestones pre-selected by NASA Goddard and the EOS managers responsible for accomplishing the major tasks as established in the work breakdown structure (WBS). In assisting NASA in arriving at the schedule, we recommend the integrating contractor optimize the schedule (spacecraft, instruments, and ground data handling system) for the lowest cost, and not for an arbitrary launch date. This would provide NASA the basis for further cost reductions.

The procedures required for operating the schedule control system for EOS would be primarily manual; they are simplified to produce the basic information at minimum cost. The master program schedule (MPS) would depict negotiated contract milestone item delivery requirements, major demonstration (design reviews) and test points, formal documentation delivery requirements, and other critical control milestones.

The summary logic network will be the basic schedule tool used to evaluate EOS project critical paths and to monitor at the project level. The summary logic network should contain approximately 300 top level events summarizing the total project. This network would be derived from, and continually integrated with, the milestone scheduling and update. The network would be a calendarized, pictorial, logic network showing key interfaces of the EOS project. Update would be done manually using the input/output data of the milestone scheduling. It would be the key schedule document used by the contractor for internal project level management and project level reporting to NASA Goddard.

Control milestones recognizing significant constraints would be established for each project phase and interrelated to WBS elements to provide the skeletal framework for constructing detailed plans for each subsystems participation. Milestone schedules would be developed within the subproject organization for all identified cost accounts and correlated within the WBS framework.

Schedule performance data would be prepared, reviewed, and submitted at the total EOS project level monthly. This top system cycle is focused at levels 1 and 2 of the WBS for management by NASA Goddard and the contractor's EOS project manager. Informal schedule monitoring and updating is done on a weekly basis.

2.4.3 Cost Control System

The EOS Phase C/D would utilize the standard contractor's accounting system which identifies all expenditures incurred by the project and records the information in a common data base. The cost control system takes the output of the financial accounting system to provide the reports necessary for effective project control. These reports fully meet the NASA 533 series report requirements.

2.4.4 Earned Value Measurement

We recommend that an earned value type of progress measurement be utilized on the EOS program. Earned value measurement is a technique which relates schedule, costs, and technical progress in such a manner that an accurate measurement of total program progress can be ascertained. It will be particularly helpful for EOS in detecting problems at an early stage so that corrective action can be applied before serious program deficiencies can happen. It should be emphasized that earned value measures work progress and not technical performance. As mentioned earlier, the quality of technical performance is determined at design reviews.

Each month the various responsible managers provide an objective assessment of the percent completion of the planned tasks. The percentage completion numbers are multiplied by the total budgeted amount giving the earned value of the work accomplished. This number is compared with the actual expenditure of EOS funds; any difference in costs gives a good indication whether overall progress is ahead or behind schedule.

A monthly report, the progress measurement report, is produced at the subsystem functional level and is the principal tool used in analyzing EOS progress measurement.

2.4.5 Reporting, Analysis, and Review

The performance measurement report would be used in conjunction with technical performance reviews, design-to-cost, and schedule control to allow managers to identify and analyze variances.

The EOS project manager would employ both formal and informal methods to monitor and control the technical achievement, including project reviews, technical interchange meetings, informal coordination meetings, and monthly progress reports. Areas covered include:

1) progress according to detailed milestone schedule, 2) inconsistencies or incompatibilities in the system specifications, 3) outstanding or potential problems and proposed solutions, 4) design-to-cost performance, and 5) cost performance.

2.5 DESIGN-TO-COST

Since the design life cycle of the spacecraft modules is 10 to 15 years, the recurring cost for fabrication of the modules is a very important factor for a cost-effective program. Because of this factor, TRW recommends that a design-to-cost program be utilized on the EOS program since it emphasizes the importance of module recurring cost. The following sections describe how a design-to-cost could be implemented on EOS.

2.5.1 General

A design-to-cost implementation approach requires early identification of cost/performance alternatives for both internal tradeoff decisions and customer evaluation purposes. Responsibilities for implementation of design-to-cost would be assigned to managers, designers, and cost estimators. Allocated production cost goals, cost estimating, and progress tracking would be used for control purposes. The design-to-cost approach involves the following fundamental features:

- Establishment and allocation of an EOS system recurring production cost goal as a design parameter coequal with program specifications.
- A formalized approach for tracking calculated recurring costs against allocated module recurring production cost goals throughout the entire program.

- Continuous tradeoff activities between cost, performance, and requirements to achieve a demonstrated recurring production cost goal at the end of the program.
- Iteration of the life-cycle-cost model in tradeoffs to minimize total life cycle costs.

Figure 2-3 shows an implementation flow diagram for a design-to-cost effort and the application of the life-cycle-cost model.

2.5.2 Management for Low Cost

2.5.2.1 Design-to-Cost Manager

A design-to-cost manager, reporting to the project manager, would be responsible for implementing the design-to-cost program. Together with cost estimating personnel, subcontracts and materiel representatives, and designers, the manager develops design-to-cost allocations for each module. If a problem develops in meeting the design-to-cost allocation for a given subsystem, he will assess the situation and recommend realignment of design-to-cost allocations for other modules, if feasible, or use of the design-to-cost allocation reserve to resolve the specific problem.

The operation of the life-cycle-cost model is also the responsibility of the design-to-cost manager. He assures that the model is used appropriately in carrying out tradeoffs and monitors results to provide management visibility.

2.5.2.2 Use of Design-to-Cost Reserve

This reserve would be the source for implementing design changes in support of design-to-cost achievement. If a preliminary design has met technical specifications, but cost estimating indicates that the allocated design-to-cost goal has not been met, the project manager will utilize design-to-cost reserve to authorize design iteration effort to reduce costs.

2.5.2.3 Tradeoff Implementation

Basic to the design-to-cost philosophy is a necessity to perform tradeoffs during all phases of the program and at all levels of the design.

Figure 2-3. Design-to-Cost Implementation Flow Diagram

If possible, within the minimum equipment performance and logistics requirements, performance can be traded for reduced cost. If it becomes evident that it will not be possible to meet minimum technical requirements without exceeding the design-to-cost goal, a study is to be prepared for review which enumerates alternatives, including life-cycle-cost effects.

To aid designers in making tradeoff evaluations and reducing production costs of their designs, cost estimators should be provided to give real-time production cost estimates for proposed designs and design alternates. In addition, designers would be provided with guidelines for piece parts and packaging costs.

2.5.3 Establishing the Design-to-Cost Goal

The EOS design-to-cost goal should be established as a recurring production cost. This design-to-cost goal would be negotiated between the customer and the contractor utilizing the best estimate of recurring production cost based on a system design which has been optimized as much as is feasible for minimum life-cycle-costs. The recurring cost will be allocated to the modules for lower level tracking purposes by the contractor.

2.5.4 Tracking and Reporting

In order to ensure real-time estimates to designers, dedicated material and manufacturing cost estimators, assigned to the design groups, can be very useful in providing real-time estimates. A key tool that can be used by cost estimators to provide real-time cost estimates to designers is a design-to-cost estimating model which is computer programmed. Figure 2-4 shows the characteristics of a TRW model along with the type of input required and output information. Through the use of this cost estimating approach, designers are able to see the effects of design changes while there is still adequate time to examine design alternatives.

The design-to-cost current estimates should be summarized at least monthly and reported by the design-to-cost manager to the project manager. The design-to-cost manager continuously tracks the latest cost estimates from the design areas and from subcontract administrators for

DESIGN TO COST

SUBMITTER'S NAME

PAGE ____ OF ____

ASSEMBLY NUMBER	QTY	NEXT HIGHER ASSEMBLY NUMBER
255230-1	0.02	256823-1

PART NUMBER	DESCRIPTION	EST. FACTORS				QTY	CODE
		A	B	C	D		
C255172-21	TRANSISTOR	8	1	3	Y	04	3
C255173-11	TRANSISTOR	8	1	3	Y	04	3
C255174-21	TRANSISTOR	8	1	3	Y	04	3
C255246-90	INDUCTOR	8	2	3	Y	04	2
C255256-30	CONNECTOR	8	3	3	Y	04	2
C255259-110	RELAY	8	3	3	Y	04	8
C255484-9	CAPACITOR	8	2	3	Y	04	2
256830-1	CRT BOARD	8	1	4	Y	04	3
256829-2	BRACKET	8	1	6	Y	04	3
PT2-16	SCREW	8	1	6	Y	04	1
SP0045-1	NUT	8	1	6	Y	04	1
SP0099-1	WASHER	8	1	6	Y	04	1

ESTIMATING FACTORS

A = MAKE (M) OR BUY (B)

B = TYPE OF ESTIMATE

C = ENCAPSULATION

D = BURDEN POOL

OUTPUT REPORT
DESIGN TO COST ESTIMATING MODELASSY NO 255230-1
QUANTITY USED IN NEXT HIGHER 2

NEXT HIGHER ASSY NO. 256823-1

PART NUMBER	DESCRIPTION	QTY	LABOR HOURS	LABOR \$ THRU G AND A	MAT'L \$ THRU G AND A	TOTAL \$ THRU G AND A
C255172-21	TRANSISTOR	12	3.6	48.60	13.56	62.16
C255173-11	TRANSISTOR	8	2.4	32.40	7.20	39.60
C255174-21	TRANSISTOR	16	4.8	64.80	17.80	82.40
C255246-90	INDUCTOR	10	3.0	40.50	40.00	80.50
C255256-30	CONNECTOR	1	2.8	37.80	25.00	62.80
C255259-110	RELAY	3	2.7	36.45	37.50	73.95
C255484-9	CAPACITOR	20	6.0	81.00	50.00	131.00
256830-1	CRT BOARD	1	1.8	24.30	1.75	26.05
256829-2	BRACKET	2	0.4	5.40	3.00	8.40
PT2-16	SCREW	4	0.1	1.35	0.50	1.85
SP0045-1	NUT	4	0.1	1.35	0.50	1.85
SP0099-1	WASHER	8	0.1	1.35	0.40	1.75
	CONFORMAL COATING	0	1.0	13.50	1.00	14.50
255230-1	TOTAL	80	28.8	388.80	198.01	586.81

MODEL FEATURES

- COMPUTER PROGRAMMED FOR THE TRW TIMESHARE SYSTEM (TRW/TSS)
- TABLES FOR MATERIAL AND LABOR RECURRING COST
 - MATERIAL COST WITH ATTRITION FACTORS AND QUANTITY PRICE BREAKS
 - FINAL ASSEMBLY
 - MAGNETICS
 - CIRCUIT BOARD ASSEMBLY
 - CIRCUIT BOARD FABRICATION
 - CABLES AND HARNESSSES
 - MECHANICAL HARDWARE
- LEARNING CURVE FACTOR FOR LABOR APPLIED AT ESTIMATED ASSEMBLY PRODUCTION QUANTITY
- REALIZATION FACTOR APPLIED TO LABOR STANDARD HOURS

Figure 2-4. Example of Design-to-Cost Estimating Model

buy equipment and reports any significant changes at weekly project reviews. The tracking and reporting system, in addition to supporting the unit production cost estimates for major customer reviews, would provide the information needed to identify potential tradeoffs between performance and cost.

2.5.5 Status Reviews

Design-to-cost reviews would be held in conjunction with all equipment formal reviews (refer to Section 2.4.1). At these reviews, the current production cost and technical performance estimates would be reviewed along with a substantiation of the data, assumptions, and methods used to generate the estimates. A formal analysis of any significant cost and/or performance problems affecting life-cycle-cost would be presented with tradeoff and analysis results leading to possible solutions.

2.6 CONFIGURATION MANAGEMENT

A formalized, properly structured configuration management (CM) system will reduce EOS costs by:

- Timely customer interface
- Simple baseline control
- Progressively increasing the degree of configuration management as the design becomes firmer
- Practicing multiple levels of configuration management.

The following configuration management approach is recommended to reduce EOS costs.

2.6.1 Baseline Control

The basic documents influencing the conduct of the program should be limited to the statement of work, system specification, and interface control drawings (ICD's) and should under the control of the customer. Any Class I changes affecting these documents are subject to customer approval. Subservient specifications such as subsystem and black box specifications should be reviewed with the customer in frequent design

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review or working meetings without formal approval required from the customer. These specifications would be under the direct control of the prime contractor.

The requirement for Part I and Part II type specifications should be deleted and a basic specification developed. Initially, this specification would contain only the requirements; as the design progresses, new details would be added to the basic specification. This deletes the requirement for identifying and controlling two separate specifications for the same item.

The functional configuration audit and the physical configuration audit should be combined into one audit. This reduces the cost of conducting two separate audits.

From a contractual standpoint only one contract end item should be identified. This would normally occur at the spacecraft level. Configured items below the spacecraft should be under the control of the design contractor. This avoids the necessity of processing Class I engineering changes to a lower level of spacecraft than is required. Customer control of the configuration would continue to be exercised through the statement of work, system specification, and ICD's.

2.6.2 Configuration Control

Black box specifications would be released after the subsystem critical design review (CDR) and would be controlled by the applicable subsystem manager. Changes affecting other subsystems would still be directed to the configuration management office. Changes occurring within the applicable subsystem would be handled internally within the subsystem until product baseline, which occurs subsequent to functional configuration audit/physical configuration audit.

A multilevel change control procedure is advocated:

<u>Level</u>	<u>Change Approval Authority</u>	<u>Baseline</u>
Spacecraft	NASA/prime contractor	Functional
Subsystem interface document specification tree	Design contractor	Allocated
Black box or module	Subsystem manager	Product

Class I changes shall be limited as they affect the contract, statement of work, system specification, and ICD's. All other changes will be classified as Class II and will be internally controlled from contract go-ahead to product baseline.

2.7 REQUIRED DOCUMENTATION

Through the years, the list of required documentation has steadily grown with each succeeding spacecraft contract. Part of this growth is due to the requirements for strong government review of contractor activities, formal documentation required by government specifications, and the natural proliferation of documents due to large contractor organizations. In addition to the many types of documents is the large number of copies required for a swollen distribution list.

TRW has studied this problem for the EOS program and attempted to make a significant reduction in the variety of documents and their distribution. Two important groundrules were used in preparing the documentation list:

- The system contractor would only prepare those documents that are essential to his internal operations
- Documents delivered to NASA for information or approval would be limited to those that have contractual implications or concerned with basic program planning.

In addition to the basic documentation list are the many documents required for the normal internal management control systems such as configuration management, quality control, cost and schedule control, etc. It is not planned that any special documentation would be prepared for the customer in these areas. The customer would keep informed of these activities through informal reviews and meetings with his residence personnel.

Using the previously stated groundrules, the documentation list is reduced to that shown in Table 2-1. TRW believes this document list meets the NASA intent for low-cost programs.

Table 2-1. EOS Documentation Requirements

<u>Formal Submission</u>	<u>Information Available Onsite</u>
Project development plan	Subsystem design review data package
Test program plan	Reliability predictions and failure modes and effects analysis (FMEA)
Configuration control plan	Nonstandard part justification
Cost and schedule plan	Failure notification
Nonconformance reports	Failure report
Parts and materials list	Spacecraft acceptance data package
Bus/payload/booster ICD's	Test procedures
Product assurance plan	Class 1 and 2 engineering changes
Safety plan	Test reports
Hazardous systems documents	Equipment specifications
Launch support requirements	Interface specifications under contractor control
Engineering drawings	Parts and material substitution list
Budget, cost, and variance report	
Preferred parts list	

3. RELIABILITY AND QUALITY ASSURANCE REQUIREMENTS

TRW studied the areas of quality assurance and reliability to determine if meaningful cost reductions could be made without jeopardizing the quality of the spacecraft. Based on this study, we estimate that quality assurance costs will be reduced approximately 15 percent and reliability costs 20 percent by applying the methods described below. In the quality assurance area we are not recommending any reduction in inspection activities but only in some areas of quality engineering. Our specific recommendations include:

- Utilize the existing quality manual of the integrating contractor in lieu of a new quality plan.
- Use proven subcontractor manufacturing processes without imposing strict conformance to government specifications
- Reduce inspection documentation
- Where possible, limit receiving inspection activities.
- Allow the contractor to control disposition of inconsequential discrepancies with informal review by NASA.
- Use standard contractor functional audits for quality assurance system. No special project audits should be used.
- Limit failure modes and effects analysis (FMEA's) to primarily those areas concerning interfaces between boxes.
- Limit reliability assessment analysis.
- Limit customer documentation to summary data.
- Reduce the formality of failure reporting and analyses.

3.1 QUALITY ASSURANCE

Most quality requirements of NHB 5300.4 (1b) are considered to be positive contributors to a low-cost program. They provide for timely inputs into the evolving design, and during fabrication and test they cause early detection of defects, minimizing costly repairs. However, there are a few modifications that would yield cost benefit without significant increase in risk.

- Quality Plans. Quality plans are submitted to provide the procuring agency visibility that the contractor understands the contractual quality aspects and has an organized approach to achieve them. Typically, contractors respond with an in-depth discussion of all controls pertinent to design, development, fabrication, processing, assembly, inspection, test, checkout packaging, shipping, storage, maintenance, field use, flight preparations, flight operations, and post-flight analysis. TRW recommends that, in lieu of an in-depth project plan, appropriate sections of the contractor's quality manual and supporting documents are submitted, thereby reducing plan preparation and associated coordination costs. The risk involved is minimal, since contractors' manuals adequately describe the quality efforts routinely conducted which meet DoD and NASA requirements.
- Specification Tradeoffs. Consideration of mission effectiveness goals prior to the imposition of process and material specifications can yield both cost and schedule savings. Adapting proven subcontractor manufacturing processes within the framework of desired government of military specifications, rather than imposing strict conformance to existing government specifications on soldering, multilayer boards, and conformal coating saves both costs and schedule time. For example, using a soft conformal coating that can be reworked and has desirable damping characteristics might be a suitable alternative for a particular application to a hard conformal coating required by strict conformance to specification which will be generally superior under all other conditions.
- Design and Development Controls. Technical documents are reviewed by personnel from various product assurance departments. For example, an equipment specification would be subject to approval by reliability, quality assurance, and PM&P specialists. Cost savings will result from a single review by a product assurance engineer representing all assurance disciplines. Also, participation of quality assurance personnel at design reviews could be limited to the producibility review without significant increase in risk. However, product assurance specialists should participate in all design reviews.
- Procurement Controls. Currently all items purchased by a contractor are subject to complete verification by receiving inspection or by contractor's inspection at the supplier. A low-cost program would identify consistently high-quality producers and subject their deliveries to minimal verification. There is some risk in this, of course, but the payoff could be substantial.

- Non-Conforming Article and Materials Control. Present practice is that when discrepant material is detected, it is segregated and dispositioned by a board representing key contractor functions, i.e., engineering, quality, parts, materials, and processes, etc. When the item is to be used as is or repaired to salvage, concurrence of the local government representatives must be obtained. Further, timely and effective actions are required of the contractor to prevent recurrence. Many discrepancies are inconsequential, unrelated in any possible way to failure mode, and therefore minimal effort should be expended at documentation, disposition, and corrective measures, etc. Disposition authority for such items could be assigned to quality assurance with a summary available for customer review. Customer participation in disposition should be limited to end items and nonperformance penalties substituted in the contract for end item failures.
- Audits. Special project audits would not be performed since functional audits of all quality elements are routinely conducted across all projects.

3.2 RELIABILITY

By judicious deemphasis on certain aspects of traditional reliability activities, there are some areas where costs can be reduced without reducing the basic spacecraft reliability. In general, these are of such a nature that they will be most effective if the contract permits some discretionary judgements by TRW and its EOS reliability manager in the execution of the reliability duties. The methods described here for affecting reliability cost savings may be characterized as follows:

- The reduction of scope of specific tasks which are of doubtful cost effectiveness
- The execution of necessary tasks in a more efficient manner by the adoption of programmatic design groundrules consistent with a low-cost objective.

3.2.1 Design Requirements

By adopting flexible design reliability requirements in the contract, some costs can be avoided without loss of design integrity. Too often an inflexible technical contractual clause forces the design one way, whereas cost and risk considerations would indicate that some other course should be followed. An example might be a clause prohibiting the existence of any single-point failures. Such a requirement could be in conflict with

a low-cost objective. It is not uncommon for the cost of correcting a single-point failure to be exorbitant compared to the small risk caused by its existence. A single-point failure design criterion is less valid for a repairable spacecraft than for previous nonrepairable spacecraft.

In a similar context, an adoption of the following design groundrules will help to reduce spacecraft costs:

- If any single-point failure requirement is imposed, confine it to that hardware related to keeping the spacecraft in a safe mode and ensuring its recovery and repairability.
- Redundancy and cross-strapping levels will be determined by performing reliability versus weight versus life-cycle cost tradeoffs, instead of designing to an arbitrary numerical reliability requirement.
- Often, designs are required to operate under the cumulative worst-case tolerance, drift, transient, and environmental conditions of all components. Since all components are unlikely to vary to the extreme in their performance simultaneously, this can be a very conservative groundrule which results in oversizing components and purchase of extremely stable components. It would be better to stipulate a required confidence that the total configuration will not drift outside established limits.

3.2.2 Failure Modes, Effects, and Criticality Analyses

The performance of a failure modes, effects, and criticality analyses (FMECA) on each and every piece part within the spacecraft is an inefficient procedure which produces a diminishing return as more and more detailed analyses are undertaken, particularly where redundancy is provided. TRW has found that, in many cases, the distinctions between the effects of one part's failure modes and those of another may be irrelevant to the execution of the design. In the interest of economy and most effective utilization of engineering manpower, FMECA activities should concentrate on those parts which a) interface with or influence a unit's redundant counterpart (and whose failure could therefore negate the intended redundancy), or b) interface with other units in the spacecraft. Those parts whose failure effects are confined to their own unit should be deemphasized.

The practice of quantifying the criticality of failure modes, determining the probability of each failure mode's occurrence, and building complex models which weight criticality and probability will be eliminated.

3.2.3 Reliability Math Models

In a program where life-cycle costs can be significantly impacted by the choice of redundancies, cross-strapping, and inherent unit reliability levels, the generation of reliability mathematical models can provide a meaningful contribution to the reduction of those costs. EOS is such a program; there are significant tradeoffs to be made between increasing/decreasing redundancy, versus the frequency of shuttle repair launches, with cost and the availability and utility of the system being dependent on results of those trades. Such tradeoffs depend on the use of math models. Therefore, reliability math models will be generated, but with significant cost-reducing changes from current practices. Among these are:

- Whenever they do not significantly conflict with the customer's data, the contractor's established piece part failure rates will be used without requiring extensive research, data collection, and documentation to prove their validity. Proof will be documented only in those instances where there is reason to doubt the validity of the contractor's data. Ball-park failure rate estimates will be used whenever the reliability estimates and resulting tradeoffs are not particularly sensitive to the value of failure rate used.
- One set of piece-part failure rates for use at nominal (or average) design conditions will be adopted and used across-the-board, without adjusting them based on each one's temperature and electrical stresses. This eliminates a costly procedure which only results in fine tuning the reliability models to an unnecessary degree. Circuit designs will, however, still be examined for use of electronic parts under excessive stress conditions.
- Average failure rates will be used for digital, analog, and hybrid IC's as a function of ranges of complexity level, rather than using the time-consuming methodologies defined in MIL-HNDBK217B.
- Reliability models will be made only to the detail and accuracy necessary to support meaningful tradeoffs. Precise models of switching, work arounds, backup modes, partial failures, etc., simply for the purpose of accuracy will be avoided.
- Reliability modeling will cease at design freeze and will not be updated following that time since the models will have already served their purpose in guiding preefreeze tradeoffs.

3.2.4 Documentation

The creation, preparation, reproduction, and distribution of documentation can be very expensive and can consume significant time of key personnel. Therefore, it will be minimized in a variety of ways. Among these are: use of summaries for the customer, with backup detailed data available for review on request (e.g., tradeoffs, mathematical models, FMECA's, failure report histories), submission of informal material for backups (e.g., work sheets, handwritten failure reports); minimization of reporting frequency; limiting distributions.

3.2.5 Failure Reporting and Corrective Action

The failure reporting system is composed of a number of forms, procedures, and review boards, all of which TRW feels play indispensable roles in reducing total program costs by detailing design and manufacturing problems early, thereby avoiding more expensive problems later in the manufacture/test cycle and in-orbit. However, on the successful NASA Pioneer Jupiter program, it was demonstrated that significant cost savings can be achieved by reducing the formalities associated with documentation of failures and failure analyses. Similar procedures should be implemented on EOS. However, established internal and customer review of logs of failures, their causes, and disposition should be rigorously maintained.

4. PARTS PROGRAM

The EOS program presents unusual requirements and opportunities for utilizing high-reliability electronic parts. Since the basic spacecraft module designs have a life cycle of 10 to 15 years, the parts program must ensure that the same parts are available over this period of time. Since many modules of the same design will be built, the volume of parts will be significantly higher than a typical one or two spacecraft program, and this affords the opportunity for large consolidated purchases. Schedule problems in supplying high-reliability parts will be significantly reduced.

In the following sections, we discuss the various parts procurement approaches and outline a program which meets the EOS requirements, while recognizing the possible fiscal constraints. The program is a significant departure from past NASA procurements, but we believe it provides the best solution for the EOS program.

4.1 BACKGROUND

Part failures in assembled hardware (especially after conformal coating) have cost some programs millions of dollars in analysis, correction, and retrofit costs. While it is cost-effective to eliminate defective parts (especially generically defective) early in hardware production, there are several schools of thought on the optimum way to do this, each valid in some applications. Practical, economic programs are likely to consist of flexible strategies for the particular case. Certainly, rigid and overconstrained parts programs have proved repeatedly to be costly and not notably effective in producing high reliability.

The principal past approaches to procurement of defect-free parts can (with some oversimplification) be described as follows:

- Produce parts on a captive line exclusively for the program with the utmost care, and avoid direct cost and schedule pressure. This approach can be highly successful when the program needs can sustain reasonable volume continuous production, and when the capital costs are consistent with the program funding and schedule. This approach is only viable for NASA programs for production of limited quantity esoteric devices (e.g., special sensors which could not otherwise be obtained at all).

- Impose on an existing commercial part extraordinary inspection, test, and process control requirements constraining the manufacturer to produce an essentially defect-free product. This has in the past tended to be the military and aerospace approach to procurement of high-reliability semiconductors, and can be very effective when practical for NASA programs. Two difficulties are apparent in present market conditions: 1) the volume of any one procurement tends to be so low that the lot-dependent costs become prohibitive; and 2) most manufacturers find a ready market for their standard product in large quantities and are reluctant to accept small orders whose requirements disrupt their production system. (TRW is overcoming some of these difficulties by embarking on standard stock procurement of high-reliability parts with a limited capital investment.)
- Procure the best commercially available part and perform lot qualification and screening tests independent of the manufacturer. Several programs have demonstrated that this approach can be effective and economical, and minimizes procurement lead time. Some risks are implicit, however, in this type of procurement. The most significant is that the yield of an acceptable product through all screening tests may turn out to be inherently zero. This can occur for a number of reasons, the most obvious being that the manufacturer has already screened out the most desirable parts for sale at a premium, so that the commercial part contains none of the desired characteristics. There is also the danger that the manufacturer may at some point make a process change that is acceptable to his commercial customers, but renders the part unsuitable for spacecraft use.

In addition to the various part procurement approaches, the EOS program presents choices in the contracting arrangements to supply parts for the initial EOS program of one or two spacecraft, including the payloads, as well as the follow-on programs utilizing the same module designs, even though they could conceivably be manufactured by another contractor.

TRW has studied the many unique and diverse requirements of the EOS program and has recommended an approach which satisfies both the short- and long-range objectives of the EOS modular design. The recommended approach is described in the following section.

4.2 RECOMMENDED PROGRAM

TRW recommends that the spacecraft integration contractor for the initial EOS procurement set up a central parts procurement program which will supply parts for all phases of the EOS program, including

follow-on phases where the module designs are the same. Since the spacecraft integration contractor for the initial EOS spacecraft may not be the contractor for all the follow-on phases, NASA should set up a separate contract for parts procurement, since this gives NASA more flexibility in awarding follow-on competitive contracts for the bus module.

By setting up a central parts procurement contract in this manner, the purchase volume of parts is raised to the level necessary to get parts suppliers to agree to meet the high-reliability parts requirements, including special screening tests and lot control. In addition, it alleviates the severe schedule problems for procurement of high-reliability parts, except for possibly the initial EOS procurement. Even in this case, the schedule should be improved, since the volume of part orders will be sufficiently large to get more attention and a better response from the part suppliers.

Since the payload instrument contractors will be under contract many months before the spacecraft system contractor is on-board, the central parts procurement plan will not have the same impact on the payload as on the bus modules.. However, the plan should still be of significant use since the payloads are expected to utilize a large percentage of the standardized parts from the central procurement. The relative time phasing of the payload contract and the spacecraft system contract will have some effect on just how many parts the payload contractors can use. Therefore, it is recommended that the payload contractor be directed to work with the system contractor in the selection of standardized parts and also to examine his design for possible modifications to increase the percentage of standardized parts.

The following sections outline the specific requirements for a centralized parts procurement program and also give estimates for the costs necessary to implement such a program.

4.3 PARTS PROCUREMENT PROGRAM

4.3.1 Standardization

Maintenance of a strong part minimization and standardization program is essential to avoid parts failures in assemblies and to minimize

other program costs. The design approach for bus functions will therefore be to use the standard parts (described below) as the basis of design, accepting other compromises whenever possible to avoid the use of non-standard parts. Designers proposals to use nonstandard parts will be justifiable largely on the grounds that the function cannot otherwise be performed. It is anticipated that nonstandard part usage in bus functions will be less than 10 percent of total part types.

Payload equipment will use standard parts as far as possible. However, experience indicates that extreme part standardization efforts are not cost effective for payloads for the following reasons:

- New and unusual parts are frequently implicit in the definition of the experiment, especially in sensor interfaces. Attempts to force part standardization in these cases are therefore inherently contradictory.
- Payloads are frequently designed and produced under the close personal care of the principal investigator under university laboratory conditions. Attempts to apply central spacecraft requirements in this environment demotivate everyone concerned without any compensating gain.
- Payload procurement is frequently not synchronized with bus procurement, which can lead to attempting retroactive standardization. This is both costly and ineffective.

Payload contractors will therefore be encouraged to use standard parts, but will be permitted freedom to adapt nonstandard parts within other program constraints. The strongest motivating factors to use the standard parts is that they will be available from a central procurement source with no schedule or procurement problems.

Standard parts will be stocked by the prime contractor and supplied as GFE to all spacecraft as defined above. Nonstandard parts will be procured by the using contractor in accordance with requirements below. Part stock quantities will be selected in light of part availability and quality projections so as to minimize program costs. In some cases (e.g., low usage critical semiconductors) the procurement may be made in anticipation of the total usage for the whole program duration. In others (e.g., most ERMIL parts), the procurement may be sufficient only to minimize schedule risk. Nonstandard part procurement will be within the scope of the hardware production contracts.

4.3.2 Standard Part Selection and Stocking

Parts will be selected for standard stock in accordance with the following guidelines:

- The part has satisfactory prior use history in comparable applications.
- There is a manufacturer willing to supply the part now and planning to continue manufacture for at least 5 years, or the procurement can feasibly be made once only for the whole program.
- A body of application on proper use (including derating) of the part is readily available prior to procurement. Especially, worst-case initial and end-of-life tolerances must be available at start of design.
- The technology of the part is such that it can reasonably be expected to be useful for the program duration (note that compromise between this goal and the first item may be necessary).

Standard parts usage (assuming redundancy is used only in a few key areas) has been roughly estimated on the assumption that 90 percent of the bus and 80 percent of the payload are standard parts, and that the payload on the average contains about the same number of parts as the bus. The bus part count for the minimum mission is approximately 19,300 parts. Therefore, the standard parts in one spacecraft including the payload is estimated as follows:

17,100 IC's

2,850 Transistor

1,710 Diodes

11,400 Passive parts

33,060

Present prices of electronic parts are estimated from costs of TRW standard stock purchase and average lot buys are as follows:

	<u>Large Lot Price (>1000)</u>	<u>Small lot (<1000)</u>
IC	\$36	\$70
Transistor	\$35	\$65
Diode	\$16	\$34
Resistors and capacitors	\$0.50 to \$3.00	\$0.75 to \$4.00

From the preceding prices, it is evident that significant cost savings can be made if the standard lot purchases are greater than 1000 parts except for passive parts. It is expected that a high percentage of passive parts can be purchased as ERMIL, which are more readily available from parts suppliers in small quantities than the active parts and will not require large lot procurement.

In the absence of any standardization program, experience indicates that most of the spacecraft parts will be small lot quantities. Making the extreme assumptions of all small lot versus all large lot buys, the maximum possible cost benefit of central stocking per spacecraft is approximately \$700,000 for purchase of active parts.

Assuming that the active parts in question belong to about 400 types without standardization for a single spacecraft, the average lot size of active parts is then only about 50 parts. This is consistent with current spacecraft experience averaged over both bus functions and payload (and without allowance for test items, attrition, etc.). A reasonable goal should be that the total number of types stocked in active parts should be of the order 100 (the vast majority of types in a list of materials are resistor and capacitor valves). The average lot size of active parts for one spacecraft is then about 200 parts plus an assumed 30 percent allowance for attrition. Cost benefit in reduced lot charges, etc., becomes effective at lot sizes of the order 1000; hence, on the average, a benefit is realized by stocking enough parts for three to five spacecraft (note that there is considerably variability about this average). The cost of active parts assuming 30-percent attrition is thus \$5 million, with a potential saving of the order of \$4.5 million for a five spacecraft lot. It is possible that some parts may have to be procured in even larger quantities to ensure their availability for a 10-year period, but a more detailed analysis is required to define a specific parts program for 10 years.

While the above is at best a very rough estimate of the effects of a standard stock program, it does indicate that substantial cost savings are possible from a standard stock program supported by a rigorous standardization program.

Of even greater significance is the fact the high-reliability parts will be available for the payload and bus without compromising the quality to meet schedules. For a modest initial investment, significant savings can be made in the purchase of parts and even greater savings by lowering the part failure rate after assembly into boxes.

4.3.3 Part Application

Design guidelines will be developed for each standard part laying down specific derating requirements. General program requirements are that:

- No significant stress exceed 50 percent of manufacturer's rated maximum.
- Semiconductors, except specifically high-power devices, operate at junction temperatures less than 125°C.

Part derating reviews will be held as part of the design review process.

4.3.4 Part Standardization Management

The system contractor establishes a parts, materials, and processes (PM and P) control board which:

- Selects standard parts
- Approves bus and nonstandard parts
- Approves deviations from application, screening, and qualification guidelines
- Supports the failure corrective action system.

The board membership includes representatives from GSFC, and the system contractors engineering, project, and product assurance organizations. A system of orderly escalation of appeal of disapprovals will be established to ensure GSFC and contractor management review of the cost-effectiveness of the PM and P control board proceedings.

Bus equipment subcontractors will establish sub-boards where membership includes representatives of the subcontractors engineering, project, and product assurance organizations, and a representative of the system contractors PM and P control board. The sub-boards perform the same functions as the primary board, except all approvals are subject to ratification by the primary board.

Payload contractors will establish systems of review of nonstandard part use by their project management. However, interface parts used by payload items will be standard parts (e.g., connectors, line drivers, and receivers).

Bus nonstandard parts may be selected if the following requirements are met:

- The function cannot within good engineering practice be performed using standard parts or
- Use of standard parts to perform the function would require an increase exceeding 10 percent in use of significant resource by the subsystem. Significant resources are power, weight, and manufacturing cost.
- The nonstandard part selected meets the program qualification requirements.

Payload nonstandard parts may be selected as required to meet performance and other requirements, and if the nonstandard part selected meets the requirements of Section 6.

4.3.5 Part Testing

Three basic conditions must be met by part lots if costly failures are to be avoided:

- 1) The basic design and manufacturing methods must be capable of producing a part having life, environmental, and electrical characteristics appropriate to the environments of manufacture, test, and use.
- 2) The processes by which the procured lots were made must be in control and in accordance with the design requirements.
- 3) The individual pieces must have been so inspected and tested as to eliminate (as far as is cost-effective) defects of workmanship or processing.

Qualification tests, lot acceptance, and screening tests for standard parts, bus nonstandard parts, and payload nonstandard parts will be assigned to ensure the above conditions are met.

Standard stock parts must have extensive use history in high-reliability applications under environments exceeding those likely to be encountered in EOS manufacture, test, and use. Contractor and GSFC existing preferred parts will be considered qualified.

Bus nonstandard parts should preferably have use history comparable with standard parts. Otherwise, type qualification testing will be performed as follows. Any test or inspection may be omitted if existing data are on hand:

- Appropriate mechanical environmental tests at a level exceeding worst-case use environments.
- Step-stressing at high-temperature operation of a sample of 20 pieces representing at least three different lots to the point all parts fail. Data from this test will be used to ensure the intended application has adequate derating, and as a basis for lot qualification.
- Radiation exposure for externally mounted or parts expected to have unusual sensitivity.
- At least one part from each of three different lots shall undergo destructive construction analysis to ensure adequacy of design and construction and provide a comparison base for lot testing.

Payload nonstandard parts may be qualified by similarity, prior use, or test. If the same part, or a part of similar design and construction, has been used successfully in comparable environments, the part may be considered qualified. Otherwise, qualification tests will be performed. Judgment of the validity of qualification data and formulation of the test requirements will be the responsibility of the PM and P control board.

Bus standard and nonstandard parts will be subject to the same lot qualification requirements as follows:

- Three parts of each received lot will be subject to destructive analysis to ensure adequacy of design, construction, and workmanship.

- Five parts of each lot will undergo step-stress testing under high-temperature operating conditions to destruction. Results must demonstrate adequate margin over any intended use, and in the case of nonstandard parts must be within the range of results experienced in type qualification.
- Parts subject to mechanical environmental damage will be subject to tests exceeding any use environment. Selection of the requirements must be made on an individual type basis, following the general guidelines of Table 4-1.

Lot qualification of payload parts will not normally be required because of the high cost of lot qualification on small quantities. Assurance of the quality of the lot would be provided, in part, by performance of destructive analysis of three samples. Certain critical parts may be proposed by the PM and P control board for special lot qualification requirements, which may be performed by the prime contractor.

Bus parts will be screened to the requirements of Table 4-1, except that existing GSFC or contractor specifications of known effectiveness and comparable requirements may be substituted. Screening will preferably be performed by the manufacturer with source inspection by the contractor. In the event that procurement of tested parts with the indicated inspection is not practical (i.e., no supplier can be found within practical cost and schedule constraints), screening will be performed by the contractor using subcontract facilities as necessary. (Pre-cap inspection cannot then be obtained.) Parts so tested will be subject to failure analysis of catastrophic screening fallout, with lot jeopardy if the results indicate a generic problem.

Payload nonstandard parts will be screened to the requirements of Table 4-2 or existing comparable specifications of known effectiveness. Screening may be performed by the manufacturer with source inspection by the contractor, or by an independent facility. In the event the screening is performed by the manufacture, three samples of each received lot shall be subject to destructive evaluation of construction and workmanship. If screening is performed independently, failure analysis of catastrophic screening fallout will be performed with lot jeopardy if the results indicate a generic problem.

Table 4-1. Parts Screening Requirements

X - Required screening O - Required screening included in MIL specification	Temperature Cycle	Vibration	Acceleration	Stabilization Bake	Seal (Gross and Fine Leak)	Maximum/Minimum and Delta Limits (Where Applicable)	Hours (Burn-in)	X-Ray
Capacitor, ceramic ERMIL	O					O	0	X
Capacitor, ceramic high stability	X					X		X
Capacitor, ceramic chip	X					X	168	
Capacitor, solid tantalum (ERMIL)	O				O	O	0	X
Capacitor, foil tantalum	X				X	X	168	X
Capacitor, glass	X				X	X	96	
Capacitor, porcelain chip	X					X	168	
Capacitor, mica	X					X	168	X
Capacitor, mylar and polystyrene	X					X	168	X
Capacitor, polycarbonate	X				X	X	168	X
Connector, electrical	Mechanical inspection only							
Diode, JANIX/JANTXV	O		O	O	O	O	96	X
Diode, general	X		X	X	X	X	168	X
Microcircuits* - Monolithic IIC	X		X	X	X	X	240	X
Hybrid, Mono DIIIC	X		X	X	X	X	240	X
Magnetics, transformer, inductor	X				X	X		(RF)
Relay, GP and latch	X	X			X	X	5000**	
Resistor, metal film (ERMIL)	O					O	0	
Resistor, metal film chip	X					X	96	
Resistor, metal film, III-Meg	X					X	96	
Resistor, wirewound (ERMIL) power						O	0	
Resistor, wirewound (ERMIL) accur	O					O	0	
Resistor, variable (ERMIL)					O		0	
Resistor, carbon composition (ERMIL)								
Resistor, temperature sensitive	X					X	96	
Resistor, networks (hermetic)	X				X	X	96	
Transistor, JANIX/JANTXV	O		O	O	O	O	168	X
Transistor, general	X		X	X	X	X	168	X
Filter feedthrough	X				X	X	250	X
Fuses	X					X	168	X
RF devices	By individual division							

* MIL-38570-CL-A or B requires no further testing

** Cycles

ORIGINAL PAGE IS
OF POOR QUALITY

Table 4-2. Payload Nonstandard Parts Survey

X - Required Screening O - Required screening included in MIL specification	Temperature Cycle	Vibration	Acceleration	Stabilization Bake	Seal (Gross and Fine) Leak	Maximum/Minimum and Delta Limits	Hours (Burn-in)
Capacitor, ceramic ERMIL	O					O	0
Capacitor, ceramic high stability	X					X	96
Capacitor, ceramic chip	X					X	96
Capacitor, solid tantalum (ERMIL)	O				O	O	0
Capacitor, foil tantalum	X				X	X	96
Capacitor, glass					X	X	
Capacitor, porcelain chip	X					X	
Capacitor, mica	X					X	96
Capacitor, mylar and polystyrene	X					X	96
Capacitor, polycarbonate	X				X	X	96
Connector, electrical	Mechanical inspection only						
Diode, JANTX/JANTXV**	O		O	O	O	O	0
Diode, general	X			X	X	X	96
Microcircuits*** - Monolithic JIC	X		X	X	X	X	168
- Hybrid, mono DIC	X		X	X	X	X	168
Magnetics, transformer, inductor	X				X	X	
Relay, GP and latch	X	X			X	X	5000*
Resistor, metal film (ERMIL)	O					O	0
Resistor, metal film chip	X					X	96
Resistor, metal film, 1/2-watt	X					X	96
Resistor, wirewound (ERMIL) power						O	0
Resistor, wirewound (ERMIL) accur	O					O	0
Resistor, variable (ERMIL)					O		0
Resistor, carbon composition (ERMIL)							
Resistor, temperature sensitive	X					X	96
Resistor, networks (hermetic)	X				X	X	96
Transistor, JANTX/JANTXV**	O		O	O	O	O	0
Transistor, general	X		X	X	X	X	168
Filter feedthrough	X				X	X	250
Fuses	X					X	96
RF devices	By individual decision						

* Cycles

** TX parts from some suppliers may require additional testing.

*** MIL 38510 Level A or B requires no further testing

4.3.6 Data System

Several measures will be taken to ensure the timely collection and distribution of information of parts problems and solutions. The system contractor will establish a system by which part problems are reviewed by the PM and P control board, and by which the board recommends corrective action for management review of cost-effectiveness. Failed parts will be collected during all manufacturing operations, and an investigation made under direction of the PM and P control board when one of the following conditions occurs:

- Numerous parts of the same type fail, causing cost and schedule jeopardy
- The part failure or failure mode is unexpected
- The part failing is critical to the successful operation of the bus
- Corrective action systems operative during integration and test will use the PM and P control board as the primary resource for part problem resolution.

5. CONTRACTING APPROACH

We have analyzed the types of contracts, the contract incentives, and the various contractor relationships that could be applied to the EOS program. We recommend the following as providing an effective contract approach at the lowest possible cost.

- NASA continues as the contracting agency for the payload throughout the program. This approach provides the greatest confidence and the lowest cost, since NASA already has an experienced team developing EOS instruments.
- A combination CPIF/CPAF contract is used for the systems integrator. CPIF incentives are used on cost and measurable parameters, while CPAF incentives are used on nonquantifiable parameters, such as management performance and payload interface management.
- The Contract Changes clause is eliminated and every departure from the original negotiated agreement is done by bilateral action (Supplemental Agreement). This eliminates questionable changes and decreases the cost of contract change administration.
- The contract provides zero fee for all contractor initiated changes and doubles the fee rate for all NASA-directed changes. This reduces the amount of change activity.
- All program cost savings originated by the contractor are shared on a predetermined percentage basis to motivate the contractor to cut costs.
- A formal contractor program is implemented for cost awareness and personnel motivation.

The following paragraphs summarize the rationale for these recommendations and discuss the means of implementing them in the EOS program.

5.1 CONTRACTOR RELATIONSHIPS

The major factors which affect the selection of the contracting approach are:

- The instrument contractors are selected by NASA and placed under contract to NASA 4 to 8 months before the system integration contractor is selected.

- Integrating the instruments into the spacecraft is the system integration contractor's responsibility.
- The system integration contractor may either build or subcontract complete spacecraft modules.

The most significant factor is the one concerning the payload contractors. In the EOS program, payload instruments fall into various categories from fully developed to early feasibility breadboarding. Because of the long lead times required for development of some payload instruments, NASA desires to begin development of certain payload instruments before the system contractor is selected. The awards for these payload elements could come in early 1975, several months before the system contractor is selected. Hence, there is a potential problem in conducting these contracts which are out of phase with each other.

There are two approaches for handling this integration:

- 1) NASA could continue as the contracting agency for the payload for the life of the program, and the system contractor would assume responsibility for all interface control, integration, and checkout. In addition, the system contractor could perform system engineering and technical direction of the payload under the direction of NASA.
- 2) After selection of the system contractor, the system contractor could assume full responsibility for development of the payload, and integrate the NASA-initiated contract into the total contract for the spacecraft.

In the first approach, if NASA continued as the procuring agency for the payload and used the system contractor as a technical advisor (an SE and TD contractor), there would be no perturbation to the payload contractor caused by the redelegation of authority to the system contractor. In addition, the payload development would proceed in the direction desired by NASA throughout the total development phase. In this approach, the payload would become GFE to the systems contractor and NASA would retain responsibility for all performance and contractual elements.

In the second approach, when the system contractor takes over the payload development he must negotiate an acceptable contract with the payload contractor, add the administrative burden costs and profits thereon to his own contract, and establish a management and technical team to

direct the payload contract, thus overall causing program costs to increase. However, this approach places full program responsibility in one place and should allow NASA to reduce its administrative and technical costs.

After examining the pros and cons of these two approaches, TRW concluded that the best approach would be for NASA to continue as the contracting agency for the payload throughout the program since the approach would ensure steady continuity in the critical area of the payload. Since NASA already has an experienced team developing instruments for EOS, this team should continue in that capacity in order that NASA has the highest confidence in achieving the performance objectives. The system contractor should be responsible for maintaining the interface control between the payload and the spacecraft bus. In addition, the system contractor would be available to assist NASA in performing tradeoff studies and resolving difficult interface problems.

5.2 CONTRACT TYPE

5.2.1 Multiple Incentive Contracts

Incentive contracting is intended to align the contract's motivation with the government's program objectives through the application of profit incentives for technical and schedule as well as cost performance. Assuming the incentives have been structured to truly mirror the government's objectives, the results depend primarily on whether the basic concepts of incentives are properly applied throughout the life of the contract. Numerous government-sponsored surveys have been made to determine the effectiveness of incentive contracting. Though some may disagree, some of the conclusions are: that incentive contracts are indeed more effective than CPFF contracts, that they do not impede attainment of technical objectives, and that the concept is sound.

In general, there has been an overreaction in using multiple incentive contracts for work in the early development phases merely for the sake of having an incentive contract, or to meet some preestablished quota for incentive contracts. Such premature application of incentive contracts on programs where there is not an adequate degree of definition and clarity of objectives hinders both the government and the contractor

in achieving the overall objectives of the program. For example, too early lock-in on technical objectives may cause research work to be subverted into design studies and thereby minimize the evaluation of technical alternatives.

To avoid such problems, multiple incentive contracts should be used only for programs, or phases of programs, in which the objectives are clearly defined and sufficiently stable to permit a continuing management toward firm objectives. The writing of work statements for incentive contracts is particularly critical because of the necessary direct relationship between the degree of explicitness in defining the work and the type of contract being used. Multiple incentive contracts should be used only if work statements and specifications are sufficiently detailed, complete, and firm. Conversely, when the government desires maximum flexibility during contract performance, a CPFF type contract should be used.

5.2.2 Award Fee Contracting

Cost-plus-award-fee (CPAF) incentive contracts are increasingly being used by NASA. Under CPAF contracts, the contractor is periodically awarded fee as determined subjectively and unilaterally by a government board employing specified evaluation criteria. Although originally associated for use with maintenance and operation type efforts, the CPAF contract now is being used to apply incentive techniques to more sophisticated contract efforts that cannot easily be evaluated objectively. Again, CPAF contracts can and do effectively motivate contractors but only to the degree they are properly administered.

The occasional practice of funding CPAF contracts at less than the maximum fee has the very realistic effect of limiting the awards received, and thereby demotivates the contractor. In effect, such action conveys the message "this is the most the government really plans to pay for awards" and the government evaluators tend to respond accordingly. Moreover, in an environment of tight government budgets, the government project manager is unlikely to request additional funding in order to award his contractor. Fully funding the maximum fee is necessary for full effectiveness of CPAF contracting, and certainly increases the contractor's motivation.

The CPAF contract evaluation criteria must specify those areas of contract performance that the government considers most important for the successful accomplishment of the job; they must be as specific as possible rather than merely an outline in broad terms. Both the government evaluators and the contractor must have a mutual understanding of the meaning, intent, and relative weightings of the criteria.

The key to effective CPAF contracting is timely feedback to the contractor, providing an evaluation of his strong and weak points so that he may correct his performance deficiencies during the next evaluation period. When such feedback does not occur, the inherent benefits of CPAF contracting can be completely eliminated.

5.2.3 Recommendations for EOS Contract Type

In establishing a specific method for implementing contract concepts, we must use those factors which will most effectively motivate both contractor and NASA personnel to optimize program goals. Since, for EOS, we interpret the primary goal to be adequate technical performance at the lowest practical cost, we believe the type of contract most appropriate for the EOS hardware phase is a combination of CPIF and CPAF for the systems integrator. In the prime contract, we recommend objective CPIF incentives on cost, as well as other program parameters which are susceptible to precise quantification and measurement. We recommend subjective CPAF incentives on those program aspects, such as flight performance, management performance, payload interface management, subcontract management, etc., which are not capable of objective assessment.

We have reviewed the question of low-cost contracting techniques for subcontractors and concluded that the choice of contracting techniques is limited. Other than the instrument subcontracts, the dollar content of individual subcontracts is not large enough to make an appreciable impact. With that view in mind, the following concepts/ideas are offered as potentially productive:

- Use fixed-price incentive subcontracts where the potential for saving cost is probable. Typically, a fixed-price subcontract presents the best assurance of change and cost control, and is

therefore, generally the preferred method of subcontracting. Incentives on cost (and possibly schedule) may present cost saving opportunities but could be disastrous if coupled with a loose specification.

- Consider the use of on-site resident representatives where expediting direction during the development, manufacturing, and test phases is critical to cost/schedule. Moreover, on-site engineering, subcontracts, and product assurance representatives could facilitate closer management control and surveillance with a minimum of data and reporting requirements.
- A corollary of the resident representatives, cited above, is more visits to subcontractors and, therefore closer surveillance facilitating management control, communication, and direction with fewer documentation requirements.

In implementing the recommended CPIF/CPAF contract for the EOS program, we recommend the following procedures for administering the incentive.

5.2.3.1 Award Fee Categories

The basic performance evaluation categories for developing an award fee structure should include program management, technical, subcontracts management, and flight performance. Each of these categories have several subdivisions which are illustrated in Figure 5-1. Most of these subdivisions are discussed in detail in other sections of this volume.

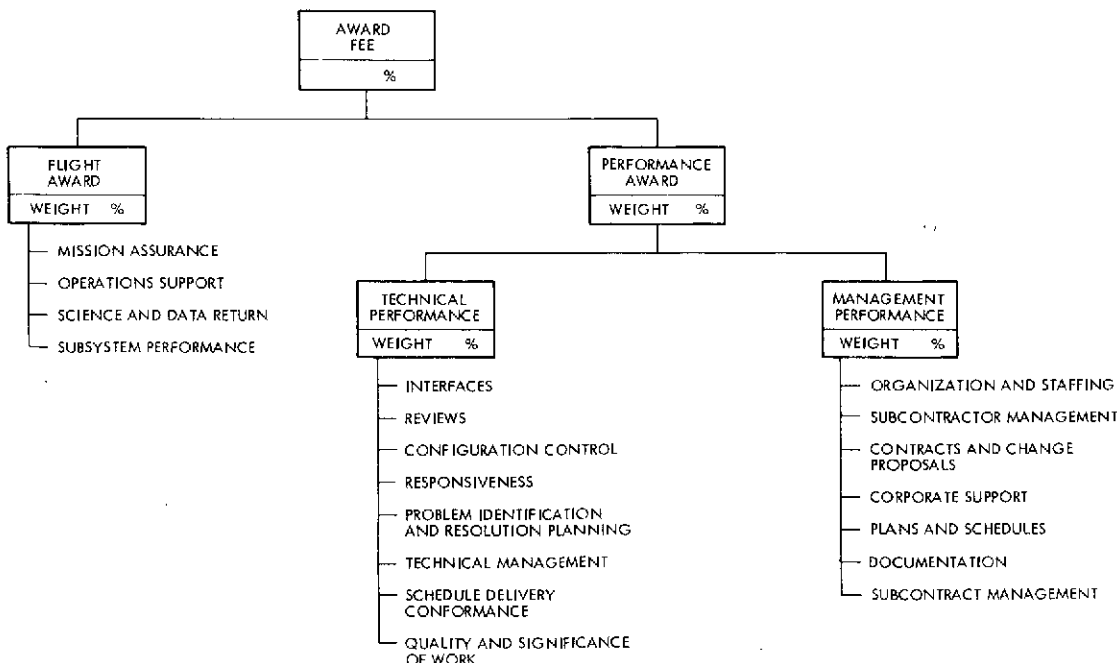


Figure 5-1. EOS Award Fee Evaluation Categories

5.2.3.2 Evaluation Procedures

For purpose of periodic award fee evaluation, a contractor award fee evaluation board should be established with membership normally restricted to project manager level. The organization for the award fee process is shown in Figure 5-2. The contracting officer should provide in advance of each scheduled evaluation period a written evaluation plan which indicates selected areas of performance of particular interest for that period. The relative weighting and importance of each period should be specified in advance by NASA. The relative weighting should be expected to change among the award fee categories for the different periods depending upon the importance of each category in a particular period.

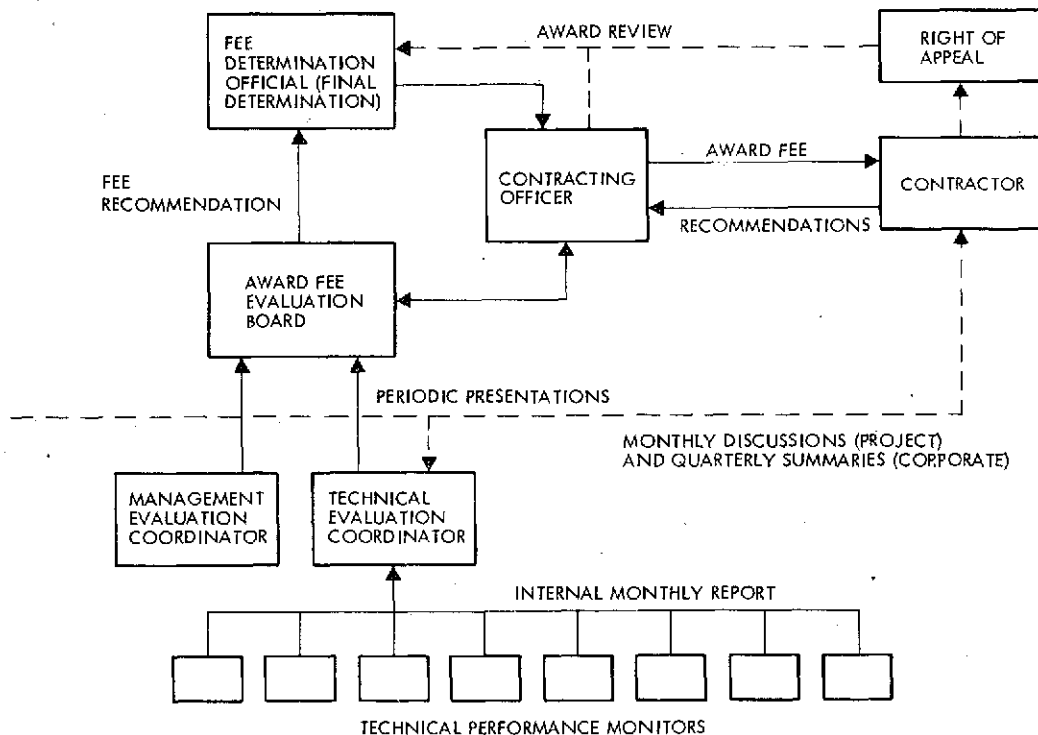


Figure 5-2. Award Fee Process

At the conclusion of each evaluation period, the contractor should prepare a brief self evaluation of progress for consideration by the evaluation board. The board should receive reports from its own evaluation. A joint review session should then be held between the

contractor and evaluation board to exchange points of view. Subsequent to this meeting, the board would submit its recommendation to the award evaluation authority.

Fees not awarded in any given period should be considered available for assignment to succeeding periods for possible awards later. Such retention of the pool would maximize motivation to encourage better performance on the part of the contractor.

5.2.3.3 Cost Awareness and Personnel Motivation

To make a low-cost achievement plan work on the EOS program, employees must be made aware of the low-cost goals, be given ideas how to achieve them, and be motivated to take positive action to meet these goals.

A concerted effort must be made to foster cost awareness throughout the contractor's organization. Positive actions should be taken to encourage new cost-saving ideas, techniques, and procedures, and to encourage expression of ideas, even if they are unconventional. There should be a continuous program to indoctrinate and motivate personnel to search for techniques for reducing costs. Several techniques and procedures designed to motivate personnel to reduce costs are recommended for EOS.

- Workshops. The contractor should conduct training and motivation sessions for managers and supervisors. Special consultants should be used to explain techniques and guidelines.
- Management Presentation. At key points in the schedule, top management should address all the team members to show total company commitment to the project.
- Incentives. Special recognition should be given to employees for innovative and imaginative efforts which result in savings of cost or time. Monetary awards, plaques, letters of recognition, and public acknowledgement are typical incentives which would be considered.

These activities should be planned to reach all levels of the program since cost-saving ideas can and do come from all levels of the team.

5.3 CONTRACT CHANGES AND TECHNICAL DIRECTION

5.3.1 General

There is no question that changes and redirection of technical work increase the cost of performing the work. This is true, regardless of whether the change is occasioned by the contractor's design, manufacturing, or testing requirements; or whether the change results from the customer's revision of the drawings, specifications, or other requirements of the contract.

To achieve cost optimization on EOS, changes should be minimized; and the few changes that are made must be implemented early in the program, when their effect can be tolerated. Well defined specifications and interface control documents must be fully agreed to prior to initiation of the work.

5.3.2 Some Innovative Concepts to Minimize Changes

5.3.2.1 Eliminate the Changes Clause

We recommend that the Changes Clause not be used for the EOS procurement. If there were no changes clause, every departure from the original negotiated agreement would have to be accomplished by bilateral action (Supplemental Agreement). These actions would involve more rigor and discipline, and there would be fewer changes. Moreover, there is an opportunity for cost-saving in the area of contract change administration. This would not preempt the rights of either party, but would ensure full understanding of the cost impact of a potential change before its authorization.

Some analysts of government procurement experience have claimed that prolific use of the standard changes clause has increased program costs as high as 40 percent, with questionable program advantages.

5.3.2.2 Use Fee to Limit Changes

There is a high-degree of sensitivity to fee or profit on the part of government and the contractor. Government personnel generally resist the application of fee, while contractors are motivated to press for it. This dynamic situation could be utilized effectively to reduce changes.

It is recommended that the contract provide zero fee for all contractor-initiated changes, and double the fee rate of the contract for all NASA directed changes. This would undoubtedly reduce the amount of change activity on EOS.

5.3.2.3 Share Savings Where Change Reduces Cost

In those instances where the contractor is able to devise techniques to reduce program cost, then such savings should be shared on a pre-determined percentage basis. To accommodate this concept, it is recommended that the current Value Engineering provision covered under Item VIII of DoD DPC-121 be incorporated in the EOS contract special provisions. Such a concept can effectively motivate the contractor to identify and implement cost savings ideas which would be of overall benefit to the program.

5.3.3 Handling Changes and Technical Direction

Four types of changes are possible on the EOS program:

- 1) Contract change notices (if the Change Clause is used)
- 2) Engineering change proposals
- 3) Cost offset proposals
- 4) Technical direction.

This section describes how technical and administrative changes should be handled and highlights the differences between proposed new cost-related procedures and those used on previous spacecraft contracts. Application of these new procedures by both TRW and NASA/GSFC should result in a lower cost at completion.

5.3.3.1 Contract Change Notices

These unilateral changes, directed by NASA under the Changes Clause, direct the contractor to proceed with the work as charged. The contractor is required to advise NASA of any resultant change in cost, fee, or schedule. In the past the contract change notice (CCN) has resulted in management decisions that frequently have been made without enough advance information as to the impact of such decisions on the program. Although rough order of magnitude cost estimates (ROM's) have

been made and verbal discussions have taken place between the parties before CCN issuance, detailed cost tradeoffs have not always been made. Occasionally there has been a sharp divergence between the contractor's claim for equity and NASA's expectation of the cost (or other) impact of the change that was directed. At times the CCN would not have been issued if the magnitude of the impact had been known early enough. In other cases, the terms of the CCN (i. e., specification limits) would have been altered to optimize the technical risk versus cost impact.

For EOS, a contract change procedure is suggested that will significantly reduce costs. The concept is simple: the problems described above will be avoided by 1) maximum precoordination between NASA and the contractor of all potential changes; 2) quick assessment by the contractor of the impact of changes on the program, followed immediately by interface meetings between all affected parties, including science and launch vehicle people, if necessary; and 3) at least tentative agreement on what the impact is before the change is implemented. Such a procedure will not be easy to implement, especially where time is a problem. But, if the impact is judged to be significant, then this cost/technical tradeoff is absolutely essential. If the proposed change is deemed to be worth the cost of implementation, then it should be negotiated. However, if there is a more cost-effective solution that is technically feasible, then the contractor should be permitted to proceed with it. Figure 5-3 illustrates the proposed change procedure.

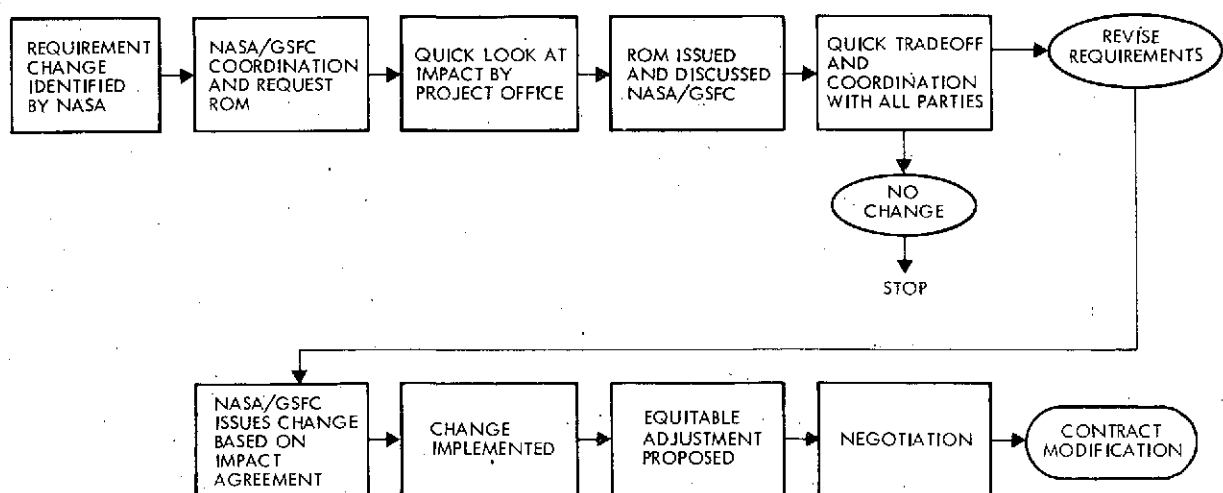


Figure 5-3. EOS Project Change Procedure

5.3.3.2 Engineering Change Proposals

Engineering change proposals (ECP's) may either be originated by the contractor or solicited by NASA/GSFC. In either case, an ECP is bilateral and can only be incorporated into the contract by means of a supplemental agreement signed by both parties. The ECP is susceptible to the same pitfalls as the CCN. Contractors frequently initiate work contemplated by an ECP before receipt of a fully signed Supplemental Agreement. Because of time pressures, the contractor normally acts on a contracting officer's letter of authorization to proceed, with no prior impact understanding or agreement. Also, the true cost versus technical requirement tradeoff is insufficient to ensure that the decision is right. Even with the ECP on the desk in front of him, the NASA/GSFC decision-maker may be tempted to make his tradeoff on the basis of what he feels he can negotiate, rather than the impact proposed by the contractor. Accordingly, until there is thorough coordination across all interfaces, and at least tentative agreement as to total impact, the change should not be implemented.

For the EOS Phase C/D, we propose to improve the discipline with which ECP's are handled. Our goal is to achieve this discipline without introducing the type of rigidity that hampers technical work, while keeping costs low. This can only be successful if there is cost sensitivity and cooperation at all levels of the contractor and NASA organization. Figure 5-4 illustrates the ECP procedure.

5.3.3.3 Cost Offset Proposal

The cost offset proposal is a relatively new concept in government contracting. It has emerged as a direct result of the low-cost philosophy of the 1970's and is not as formal as a CCN or an ECP. Basically, the idea is that the overall mission and project cost are the dominant elements of the program, while detailed specifications and other lower level requirements are secondary. If a specification value is a significant cost driver, and if that value can be altered without jeopardizing the mission, then it is a candidate for change even if some technical risk may be introduced into the program by reduction of design margins or technical

contingencies. These deviations or waivers to the agreed-on specifications or other contract requirements have met with considerable resistance in the past.

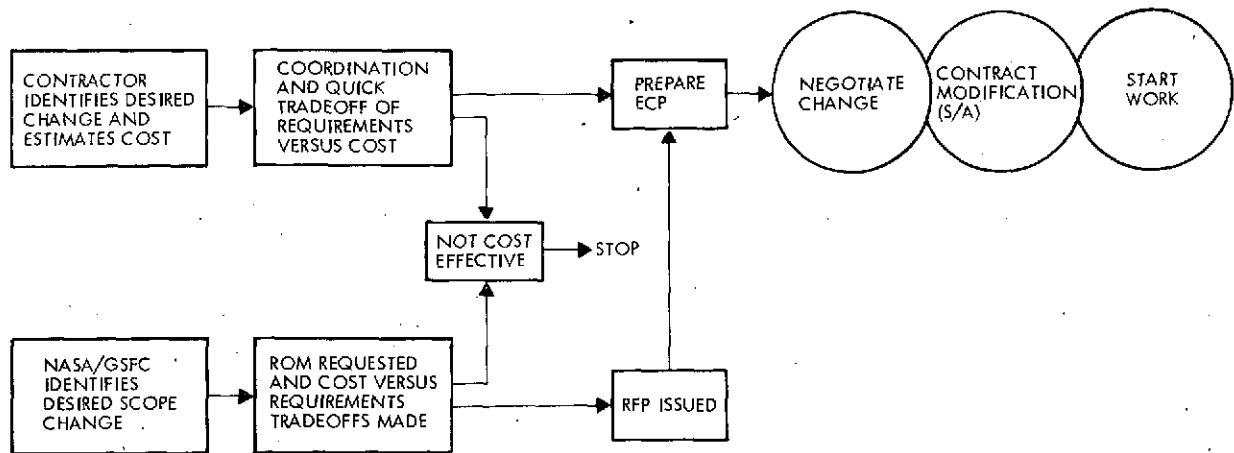


Figure 5-4. Engineering Change Proposal Procedure

We recommend that the cost offset proposal be used in EOS, and that the contractor be directed to look for ways to offset any cost growth that may develop from unexpected technical problems. When potential offsets are identified, they will be presented to NASA/GSFC in the form of letter proposals. These proposals may: recommend elimination of a prescribed test and substitution of analytical data; ask for relief on the stated weight allowance for the spacecraft, suggest the deletion of a report which is no longer being used; or propose a new spares philosophy. In any case, we see the offset concept as a process for continuously bringing the estimate-at-completion into line with the negotiated contract cost.

Realization of NASA's objective of a low-cost EOS program may depend on the contractor's implementation of this cost offset proposal concept and NASA/GSFC's early response to proposal submissions. Positive participation and action by both the contractor and NASA/GSFC are essential.

Although cost-offset proposals are less formal than ECP's they are handled in much the same way. A cost offset proposal may result in a

specification change and contract modification, but it will not usually involve a change in the estimated cost of the contract. The important thing is that the cost offset proposal, when accepted by NASA, will result in a lower overall cost to the government than would otherwise have been experienced.

5.3.3.4 Technical Direction

Technical direction that is within the scope of work would not result in a claim for equity. If technical direction does not result in added scope, we would advise the contracting officer and follow the same procedure as for the changes. Regardless of the question of scope, there must be greater discipline for EOS, particularly with respect to informal technical direction.

The contractor needs to explore with NASA/GSFC the importance of each directed action that is a cost driver. We believe that the contractor team can help NASA/GSFC with cost tradeoff decisions and possibly offer alternative courses of action that would lower costs. Figure 2-5 demonstrates this concept.

In Figure 5-5, the decision to implement the change is made on the basis of tradeoff evaluation before the question of in-scope or out-of-scope is addressed. This is important, since the fact that a direction is within scope does not necessarily mean that it can be accommodated at no cost. The only distinction between the two is that in-scope direction does not bear additional fee. When the decision to implement technical direction is made on the basis of worth to the program, then we can be sure that this type of change will be made only when absolutely necessary.

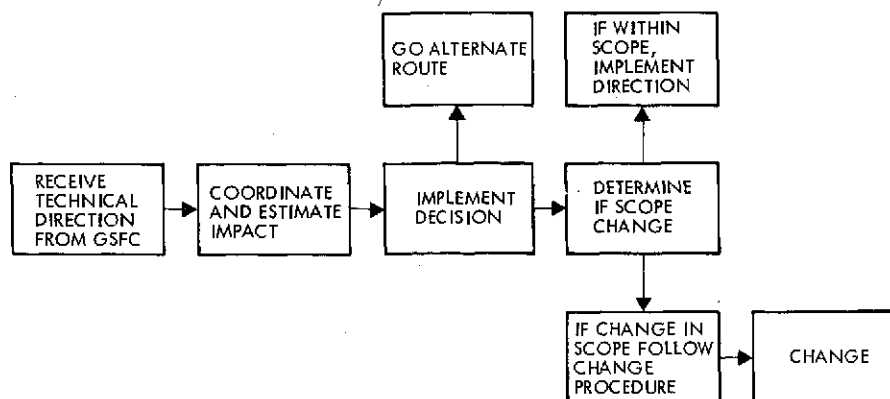


Figure 5-5. Implementation of Technical Direction Changes